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Economic and Optimization Study of an Hybrid Solar-Diesel System for A Coaster Area in Lagos State

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Abstract: **Photovoltaic power system has become most acceptable renewable energy system for rural areas that do not have access to grid system. This system was designed to supply electricity to Akodo which does not have access to the national grid network of power supply in Nigeria. Akodo, a community in Ibeju Lekki Local Government Area of Lagos State, which is made up of about 150 houses and requires about 89KW load which can be supply conveniently by the solar diesel system, is found to be more appropriate in this research work. The initial cost seemed to be on the high side, but on the long run the maintenance of the system which was very minute accorded the system significant advantage. It is now economical to embark on this research work which would be found to be highly beneficial.**

Keywords: **Battery, Diesel Engine, Inverter, Photovoltaic power System.**

1. INTRODUCTION

Photovoltaic power system has become most acceptable renewable energy technologies because depletion of non-renewable energy every day brings about the use of solar system to generate electricity in our present days world. Electricity is generated from the sun radiations through the use of semiconductor (silicon) cells which are arranged in arrays to form a solar panel. The true origin of the solar panel is from cells, but technology has improved on that with the use of organic solar cells which are more flexible and lighter called conducting polymer By using only diesel generator, the percentage of carbon dioxide in the atmosphere will increase, causing global warming and drastically increase the depletion of ozone layer which protects the earth from direct infrared radiation. Therefore, it is very important to reduce this through the use of PV/DG hybrid system which provide minimum negative environmental impacts and cost friendly.

In 1838, French physicist Alexandre Edmond Becquerel experimented that some material produced small amount of electric current when exposed to light, and in 1946, this resulted into the development of photovoltaic cells by Sven Ason Berglund which is now solar technology. The sun is the most readily and widely available sources capable of delivering energy demand through solar radiation falling on solar panel with maximum flux density of about $1kw/m^2$ and wavelength of band between 0.3 and 2.5µm. The PV system produced DC which is used to power DC loads or Ac loads through a converter (or inverter) and excess energy produced can be stored in a battery for usage when the radiation power is low compare to the demand. PV output might not be enough in a day due to bad weather or cloud covering and also if there is no enough energy on the storage (batteries) device to supply the load. Hence, it is necessary to run a diesel generator to power the load as well as charging the batteries simultaneously pending the time that there will be enough energy on the batteries to power the load and the generator will be cut off as the supply. This will reduce the number of hours to run a generator and drastically save some fuel cost with reduce environmental pollution effect.

1.1 Aim and Objective:

In this work, our aim is to design hybrid solar and diesel power for Akodo community, a coastal area in Lagos State, Nigeria. In the remote rural areas, where the grid extension is difficult and not economical, hybrid energy systems stands as a simple solution for rural electrification project. Such system incorporates a combination of one or several renewable energy sources including solar photovoltaic, wind energy, micro-hydro and conventional generators if need be for any power Backup.

2. HISTORY OF HYBRID POWER GENERATOR

2.1 Status of Electricity:

Nigeria is a developing country where majority of people, about 60% of the total population live in the rural areas. This large population in the remote and rural areas is deprived of electricity from the conventional electrical grid. Total installed capacity for electricity generation is about 6000 MW (as at December 2013), whereas the maximum generation is around 3500 MW and electricity demand is about 10000 MW at the moment. The electricity demand is increasing day by day, and is also expected to be triple the present quantity by 2020. The government of Nigeria sets a target of providing electricity for all by the year 2020 to the tune of over 10,000 MW; however the demand of electricity is increasing annually by significant percentage. Due to the high cost of expansion of electrical transmission and distribution networks, most remote and rural areas are not connected to the national grid and the possibility of connecting those areas with the conventional grid network in near future is low for the few communities connected to the electricity supplied is unreliable. In the case of the community in this study, (Akodo community), the inhabitants have been out of supply for a couple of years. This informed the design of a renewable means of power supply to reduce the nightmare being experienced as a result of lack of power supply. The stand-alone or off grid hybrid renewable energy generation system can be a suitable alternative option for providing electricity in rural and remote communities, Akodo community of Lagos state, inclusive . The problem of unavailability of electricity from national grid has made various researchers to develop alternative ways of energizing the communication base satiations with wind power, solar generator, or solar/wind/diesel generation system. Example of this can be found in Airtel base station in Benin Site where wind/solar/diesel generator were hybridized to power the station efficiently (Airtel monthly magazine, 2014) (15), PV solar/wind hybrid energy system for GSM/CDMA type mobile telephony base station in Indian (Pragya et al, 2010) .The use of renewable energy resources is not for rural areas alone, business investors, different appliance and general electrification through hybrid system has been designed and operated over years (Boyo. 2003), application of demand side management to hybrid energy system model for rural electrification (Babatunde, 2014) and so on as a method for making power available for rural users has been done.

2.2 Theoretical Background of the Study:

There are two different ways by which solar system can be utilized to convert the irradiation into electricity, one method is by collecting solar energy as heat and converting it into electricity using a typical power plant; the other method is by using photovoltaic (PV) cells to convert solar energy directly into electricity, most research and thesis utilize the second approach which is highly dependable on radiation of sunlight.

2.2.1 Solar Potential Analysis in Nigeria:

Wind speed, temperature, rainfall, solar radiations data are always differ from one areas of location to another; these meteorological conditions are always viable in the design of any renewable energy generation system (3). For efficient operation of renewable system involves solar panels, solar radiation should be obtain for the site of project at the stage of planning. In recent years, the Nigerian government has paid more attention on solar energy applications for municipal amenities (like street lightings).

In Nigeria, only few areas have records of daily solar radiation to that effect. Several empirical formulae have been developed to calculate the global solar radiation using various parameters. These parameters are: the sunshine hours (Angstrom, 1924; Black et al, 1954); the relative humidity and sunshine hours (Gopinathan, 1988); the declination angle and the latitude (Liu and Jordan, 1960); sunshine duration, relative humidity, maximum temperature latitude, altitude and location (Sabbagh et al, 1977) and the total precipitation, turbidity and surface albedo (Hoyt, 1978). (4)

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The monthly means daily sunshine duration, maximum temperature, cloud cover and relative humidity used for any study can be obtained on NASA website or archives of the Nigerian meteorological Agency, Oshodi, Lagos as obtained for this designed work. From various result obtained, it was observed that sunshine duration varies with location and period of the year, it is very in Sokoto (80.7% maximum in December and 49.1% minimum in August) next to this is Ilorin (71.1% maximum in December and 30.4% minimum in August), Abeokuta (49.9% maximum in February and 22.6% minimum August) and the least is in Port Harcourt (43.6% maximum in December and 14.2% minimum in July). In general, sunshine duration in Nigeria is very high from November to April and low in July to August. (Olayinka, 2011).

Inverter

This is required to convert the direct current (DC) power produced by the PV module into Alternating current (AC) power. Most solar power systems generate DC current which is stored in batteries while nearly all lighting, appliances, motors, pumps and so on, are designed to use AC power, so it takes an inverter to make the switch from battery stored DC to standard power (240VAC, 50Hz). In the sizing of the solar inverters, it should be noted that the inverter should be 25-30% bigger than the total Watts of all appliances that are be powered by the system. It must also be able to handle the expected surge or in rush of current that some large loads draw upon.

Battery

Almost all type of renewable system uses an energy storage battery to keep critical load circuits operating when there is a power outage due to insufficient radiations. When an outage occurs, the unit disconnects from the OV and powers specific circuit. If the power outage occurs during the day, the PV array is able to assist the battery in supplying the critical load.

3. DESIGN METHODOLOGY

3.1 Site Survey of Akodo Community:

Akodo community is located in Ibeju Lekki local government of Lagos state of Nigeria, around latitude 06° 25^1 north latitude and 03° 24^1 east longitudes. Communities in its environs include Imagbon, Idotu , Eleko and Bogije. It is a water front area and has beaches, including the popular Eleko beach around it. The residents of the communities are mainly fishermen, farmers and traders. The community has no access to grid-supplied electricity and relies on few individual portable diesel-generators for electricity. There is a potential for electricity generation from solar resources and diesel generator based on daily solar irradiation between 63.813 and 74.127 kWh/m^2 / day.

In this study, a hybrid power system of solar PV and diesel generator is proposed power for the community's load demand of 88.9kw. In this study, HOMER (Hybrid Optimization Model for Electric Renewables) software is used for system simulation and cost analysis. For the simulation, input information includes electrical load demand, solar and diesel generator, technical specification of different components, costs, type of load dispatch strategy etc.

3.2 Solar Energy Resource Availability in Akodo Community:

Solar energy is received from the sun's rays that reach the earth being converted to energy through different processes. Solar can be converted to electricity via Photovoltaic cells or panels. Solar irradiance, a measure of incoming solar radiation of Akodo is very good for the purpose of electricity generation. The monthly average global radiation data obtained from Nigeria Meteorological Agency (NIMET) is about 8.084kwh/m 2/day. The clearness index is a measure of the clearness of the atmosphere with an average value of 0.813 for Ibeju Lekki local government of Lagos state. Table 1 shows the clearness index and daily radiation for the local government; it also shows the monthly averaged values of clearness index and daily radiation.

Table3.1: Solar resource values for Akodo community (REF: NIMET).

Month	Clearness Index	Daily Radiation (kWh/m^2/Day)
January	7.0	65.346
February	6.9	68.258
March	7.0	72.552
April	7.1	74.127
May	7.1	72.268
June	7.4	73.658
July	3.0	30.062

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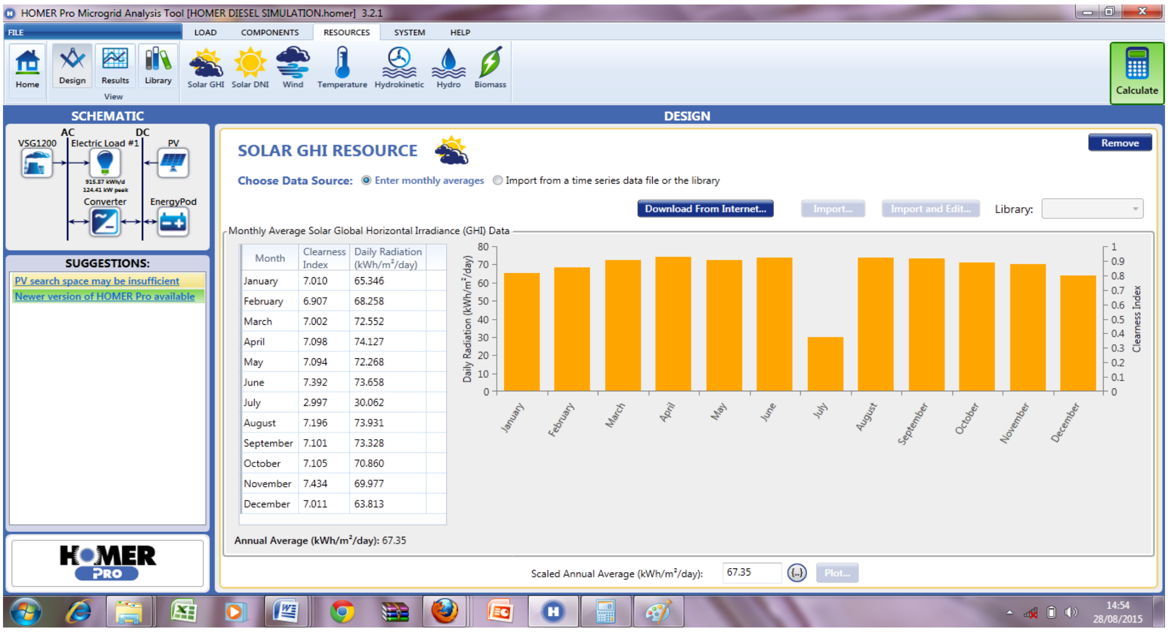
August	7.2	73.931
September	7.1	73.328
October	7.1	70.860
November	7.0	65.977
December	7.1	63.813
Annual Average	0.813	8.084

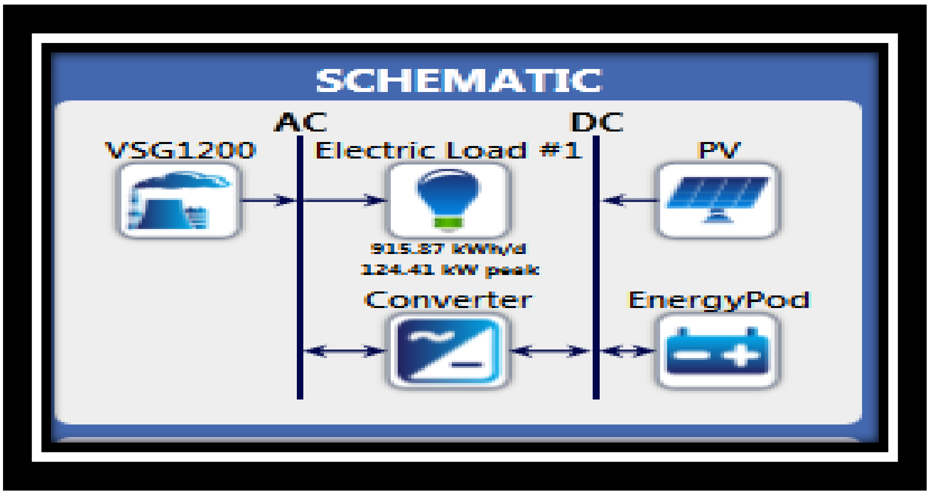


3.3 Diesel Generator (DG)

The DG (Innovus VGS 1200) will run from 6am to 10am during which time that the PV and the battery output will be low. PV will run for the remaining period except if the radiation energy is low during the day. The energy stored in the battery can as well be used. During this period the “forced on” light will come on. The forced light showed red when the generator did not come on. Optimised on the system will sense the condition of the generator and PV to know when either of the two should come on.

3.4 Design of Hybrid Energy System For:

Solar and DG has been chosen due to its operating reliability and low cost, quick start and small size. It has good thermal and electrical efficiency. Moreover, it has low fuel consumption and good load support. The figure below shows the connection of the solar and DG hybrid power system with its accessories.



Solar and Diesel Generator System

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3.5 Load Profile:

The load profile is the basis for designing the projected hybrid system by using simulation software. Generally the load profile is the determination of electrical load distribution in any area which is generally measured of 150 users daily or monthly basis. In this study, a hypothetical model area in Akodo community is considered. In the community, there are four Shops, two Salons, two Poultries, three Churches, two Mosques one Primary School and one Secondary School. The electricity consumption in the households of the rural areas is comparatively lower than those of urban areas. A rural household generally uses electrical energy for lighting, cooling and entertaining. Each Akodo household is considered to consume about 3W made up of energy efficient lamps (compact fluorescent bulb, 15W each), 2 ceiling fans (80W each) and 1 television (100W). The daily average hours of use the light and TV are 6-7hrs, fan 16-17hrs . The primary load or energy consumption pattern usually varies daily and monthly of the year. The tables below show the load and energy demand for Akodo household.

Table 3.3 Load Input 1

HOURLY LOAD [W]	00h	01h	02h	03h	04h	05h	06h	07h	08h	09h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Energy	[Wh]
Fan	100	100	100	100	100	100	100	100	100							100	100	100	100	100	100	100	100	100	1800	
Radio						80	80	80	80							80	80	80	80	80	80	80	80			
Kitchen light					40	40	40	40												40	40	40	40		320	
Bathroom					40	40	40	40												40	40	40	40		320	
Bedroom light						40	40	40												40	40	40	40		280	
sit Rm light					40	40	40	40											40	40	40	40	40		360	
Television																120	120	120	120	120	120	120	120			
TOTAL [W]	100	100	100	100	220	340	340	340	180	0	0	0	0	0	0	300	300	300	340	460	460	460	460	100	5000	[Wh]
Number of users	150																									
TOTAL USERS [kW]	15	15	15	15	33	51	51	51	27	0	0	0	0	0	0	45	45	45	51	69	69	69	69	15	750	[kWh]
Demand factor	0.8																									

Table 3.4: Load Input 2

HOURLY LOAD [kW]	00h	01h	02h	03h	04h	05h	06h	07h	08h	09h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
TOTAL DEMAND	12	12	12	12	26.4	40.8	40.8	40.8	21.6	0	0	0	0	0	0	36	36	36	40.8	55.2	55.2	55.2	55.2	12
Shops									20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	
Salon									15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7			
Poultry	8	8	8	8	8	8	8	8												8	8	8	8	8
Church						2	2	2												2	2	2	2	2
Mosque						2	2													2	2	2		

3.6 Homer Input Summary:

Location	
Latitude	6 degrees 31.55 minutes North
Longitude	3 degrees 20.39 minutes East
Time zone	Africa/Lagos

Load

Data source	Synthetic
Daily noise	10%
Hourly noise	20%
Scaled annual average	915.870 kWh/d
Scaled peak load	124.4114 kW
Load factor	0.3067

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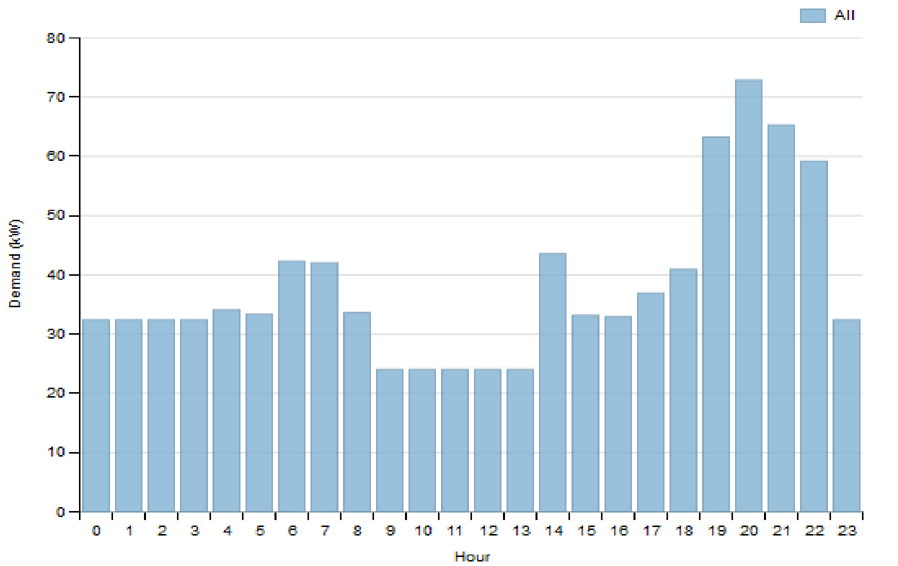
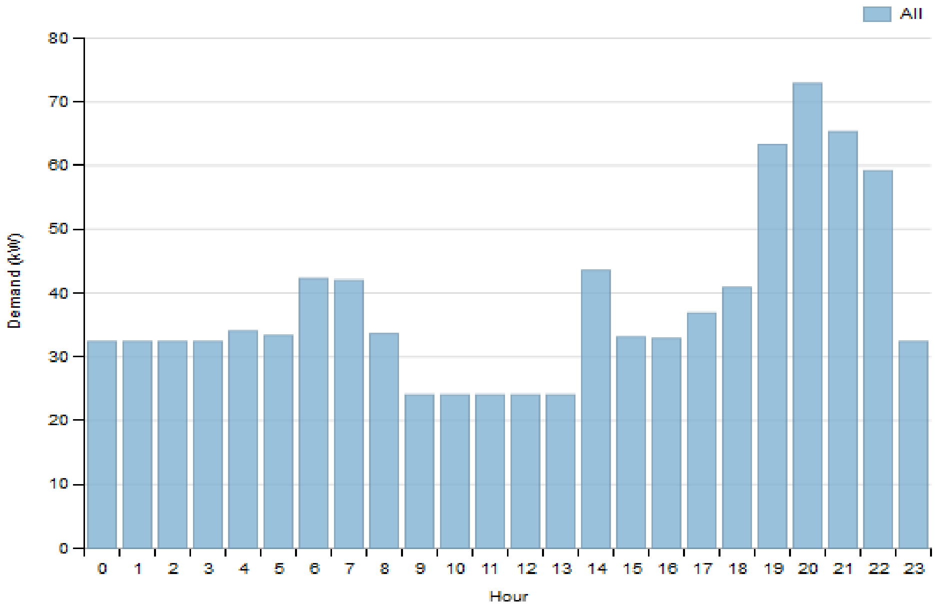
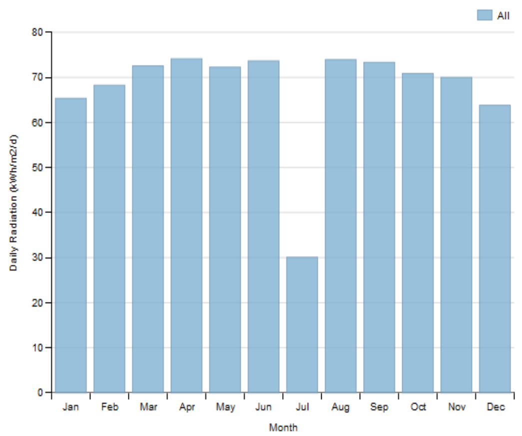




Solar Resource

Scaled annual average	67.35 kWh/m2/d



PV: Generic flat plate PV

Size	Capital	Replacement	O&M
0.35	¤533.00	¤450.00	¤0.20
950.00	¤1,446,714.00	¤1,446,600.00	¤5.00

Sizes to consider	0.35,950
Lifetime	25 yr
Derating factor	80%
Tracking system	No Tracking
Slope	6.526 deg
Azimuth	0.000 deg
Ground reflectance	20.0%

Generator: Innovus VSG1200 Copy

Size	Capital	Replacement	O&M
1.00	¤320.00	¤320.00	¤0.30
1,200.00	¤250,000.00	¤250,000.00	¤8.00

Sizes to consider	1200,500,1
Lifetime	33,600 hrs
Min. load ratio	0%
Heat recovery ratio	0%
Fuel used	Diesel
Fuel curve intercept	0.0031 L/hr/kW
Fuel curve slope	0.2492 L/hr/kW

Fuel: Diesel

Price	¤ 0.47/L
Lower heating value	43.2 MJ/kg
Density	820.00 kg/m3
Carbon content	88.0%
Sulfur content	0.3%

Battery: 280kW-1MWh Primus Power EnergyPod

Quantity	Capital	Replacement	O&M
1	¤179,257.00	¤179,257.00	¤0.00

Quantities to consider	0,1
Voltage	840 V
Nominal capacity	1,200 Ah
Lifetime throughput	[1000] kWh

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Converter

Size	Capital	Replacement	O&M
1,000.00	¤300,000.00	¤300,000.00	¤100.00

Sizes to consider	1000,0 kW
Lifetime	15 yr
Inverter can parallel with AC generator	Yes

Economics

Annual real interest rate	6%
Project lifetime	25 yr
Capacity shortage penalty	¤0/kWh
System fixed capital cost	0
System fixed O&M cost	0

System control

Check load following	No
Check cycle charging	Yes
Setpoint state of charge	80
Allow systems with multiple generators	Yes
Allow multiple generators to operate simultaneously	Yes
Allow systems with generator capacity less than peak load	Yes

Emissions

Carbon dioxide penalty	¤ 0/t
Carbon monoxide penalty	¤ 0/t
Unburned hydrocarbons penalty	¤ 0/t
Particulate matter penalty	¤ 0/t
Sulfur dioxide penalty	¤ 0/t
Nitrogen oxides penalty	¤ 0/t

Constraints

Maximum annual capacity shortage	0
Minimum renewable fraction	0
Operating reserve as percentage of hourly load	10
Operating reserve as percentage of peak load	0
Operating reserve as percentage of solar power output	25
Operating reserve as percentage of wind power output	50

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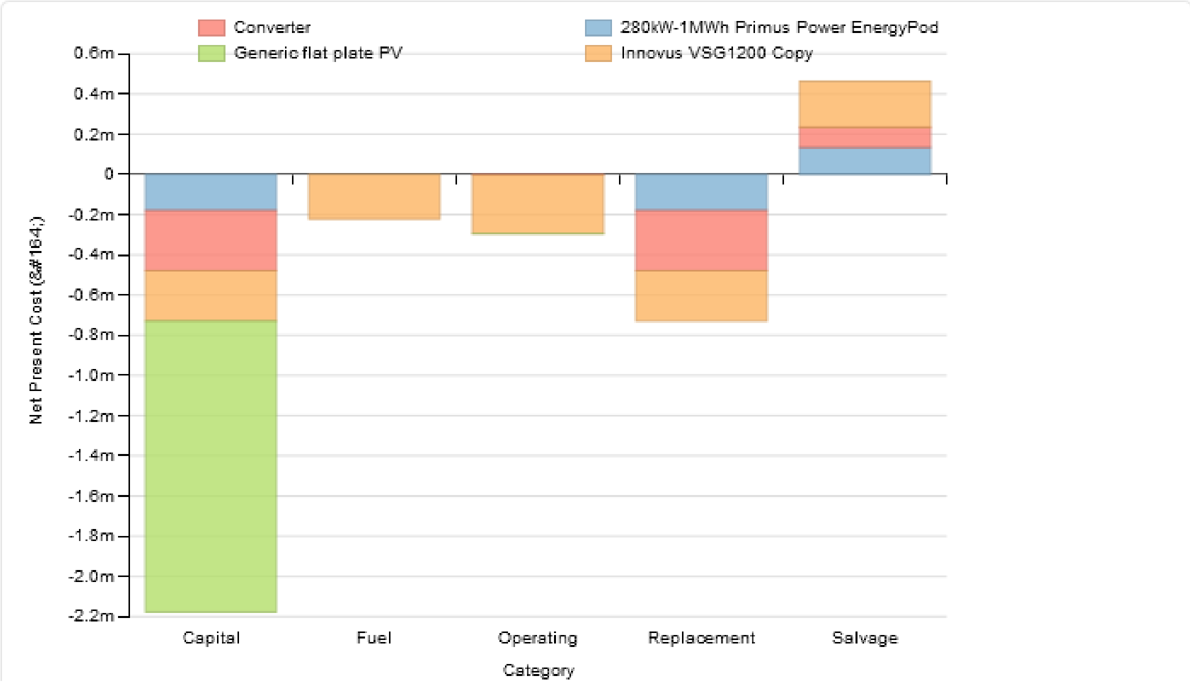
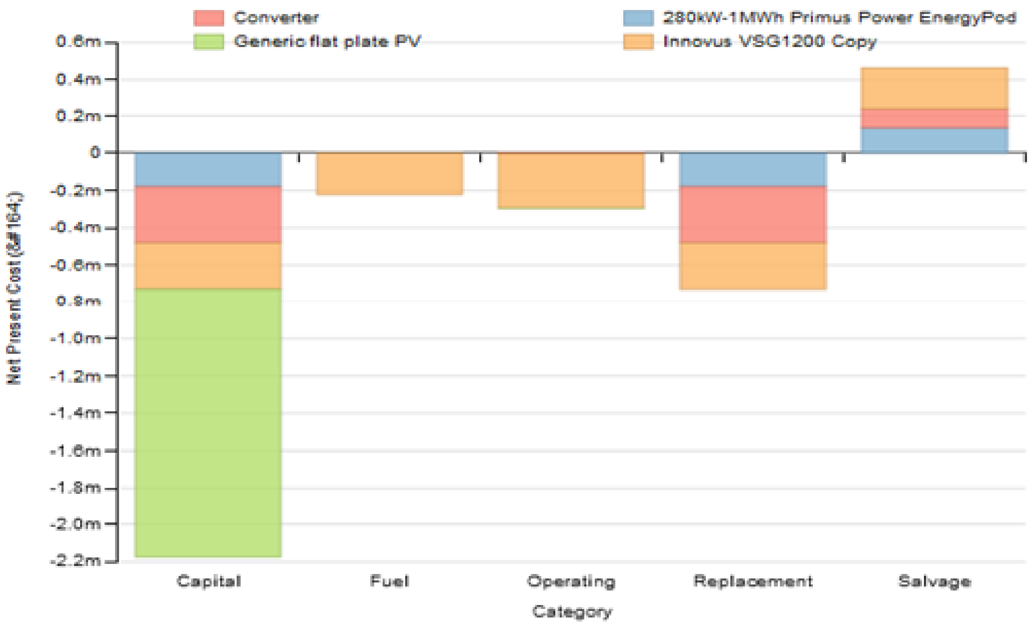
4. ANALYSIS OF RESULTS

For the hybrid system designed for the Akodo community, the PV panels, VSG 1200, the batteries and the Converter systems were configured and simulated using HOMER software. The results generated from the software are shown in the Tables and the corresponding Charts given below.

System Report System architecture:

PV	Generic flat plate PV	950
Generator	Innovus VSG1200 Copy	1,200
Battery	280kW-1MWh Primus Power EnergyPod	1
Converter	System Converter	1,000
Dispatch Strategy	Cycle Charging	





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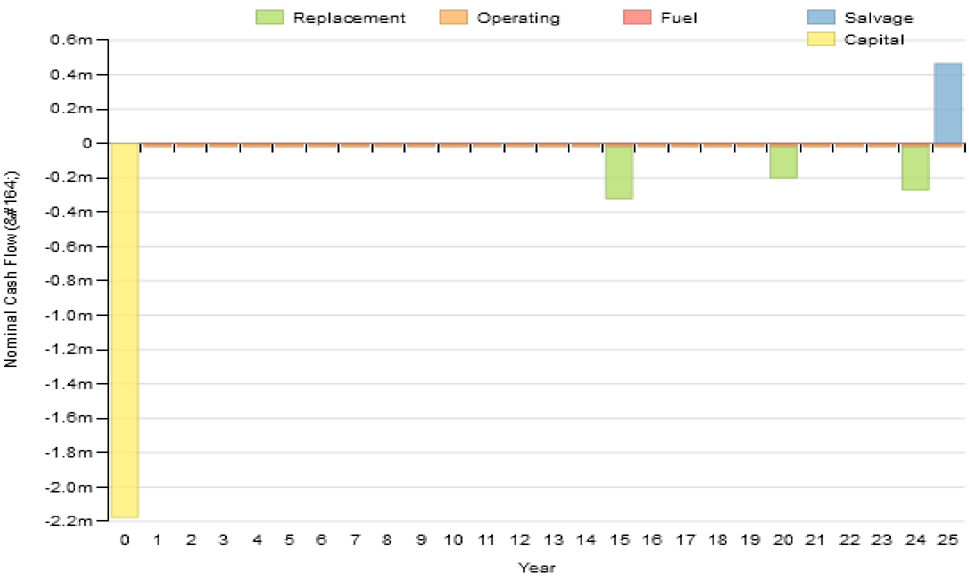
Total net present cost	2583677
Levelized cost of energy	0.598

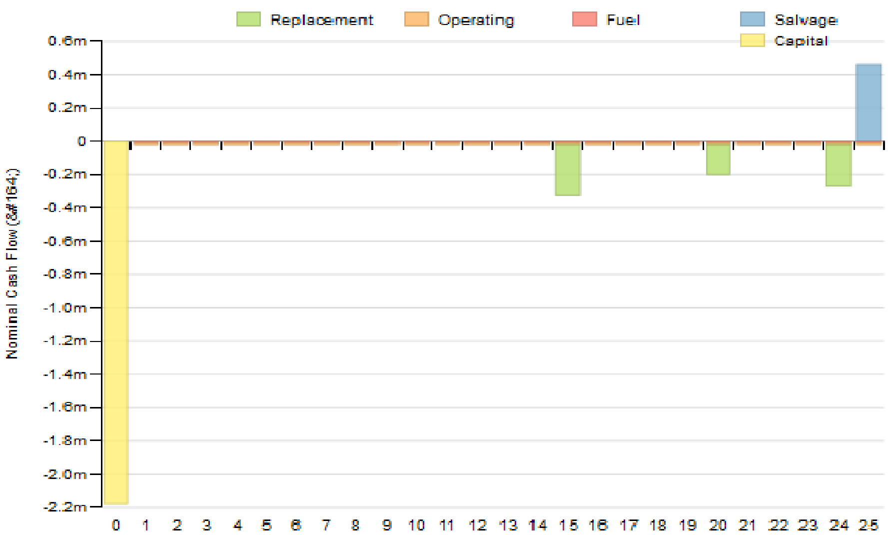
Net Present Costs:

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
Generic flat plate PV	1,446,714	0	65	0	0	1,446,779
Innovus VSG1200 Copy	250,000	67,090	150,993	114,718	-54,720	528,081
280kW-1MWh Primus Power EnergyPod	179,257	57,148	0	0	-32,207	204,198
Converter	300,000	127,282	1,293	0	-23,956	404,619
System	2,175,971	251,520	152,351	114,718	-110,883	2,583,677

Annualized Costs:

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
Generic flat plate PV	111,910	0	5	0	0	111,915
Innovus VSG1200 Copy	19,339	5,190	11,680	8,874	-4,233	40,850
280kW-1MWh Primus Power EnergyPod	13,866	4,421	0	0	-2,491	15,795
Converter	23,206	9,846	100	0	-1,853	31,299
System	168,321	19,456	11,785	8,874	-8,577	199,859





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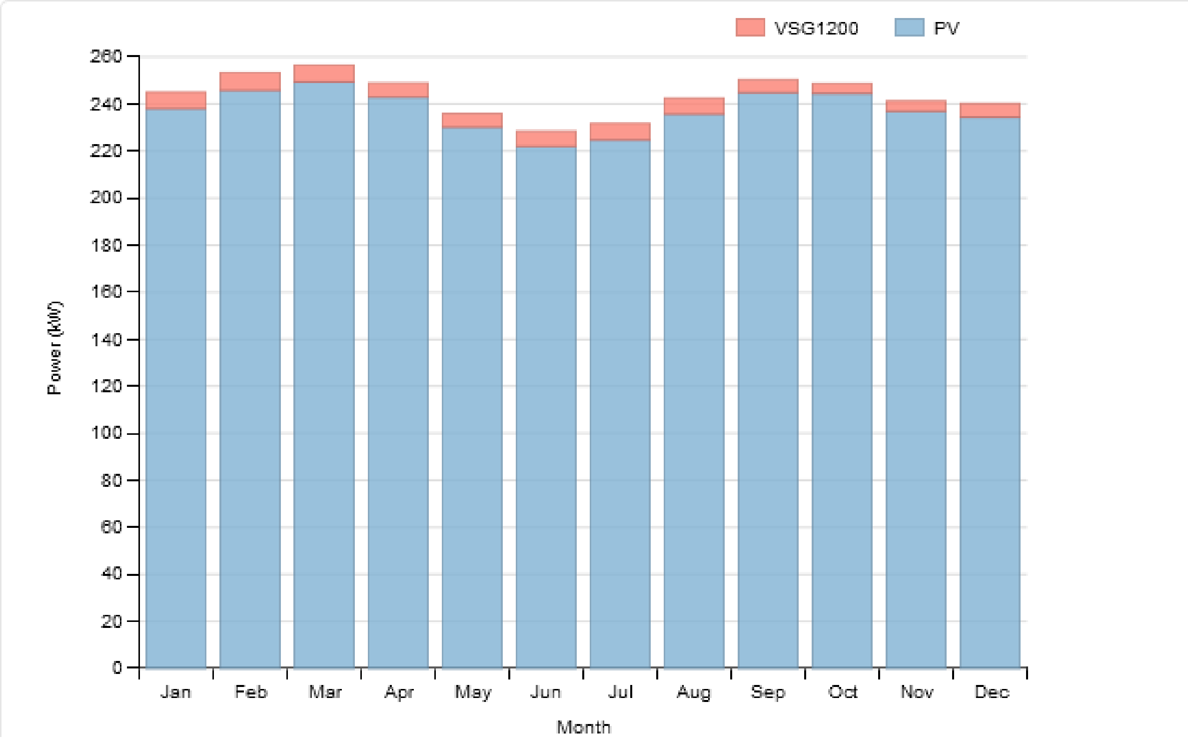
Electrical:

Quantity	**Value**	**Units**
Excess electricity	1673871	kWh/yr
Unmet load	0	kWh/yr
Capacity shortage	0	kWh/yr
Renewable fraction	1	
Component	**Production(kWh/yr)**	**Fraction (%)**
PV	2,079,319	97
Generator	53,692	3
Total	2,133,011	100

Load	Consumption(kWh/yr)	Fraction (%)
AC primary load	334,293	100
DC primary load	0	0
Total	334,293	100



PV: Generic flat plate PV

Quantity	**Value**	**Units**
Rated capacity	950	kW
Mean output	237	kW
Mean output	5696.80	kWh/d
Capacity factor	24.99	%
Total production	2079319	kWh/yr
Minimum output	0.00	kW
Maximum output	778.02	kW
PV penetration	622.01	%
Hours of operation	4315	hrs/yr
Levelized cost	0.054	£/kWh

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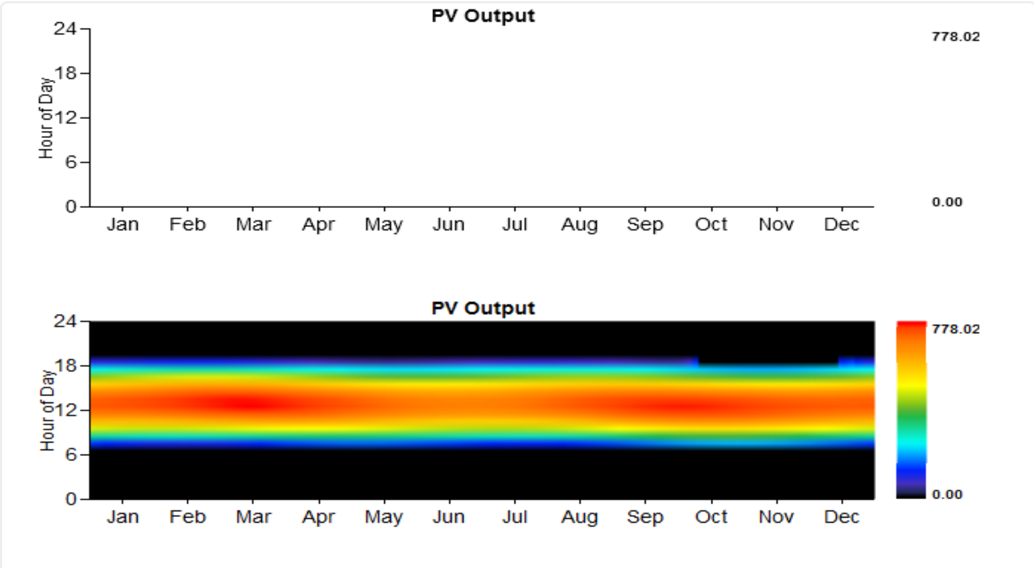
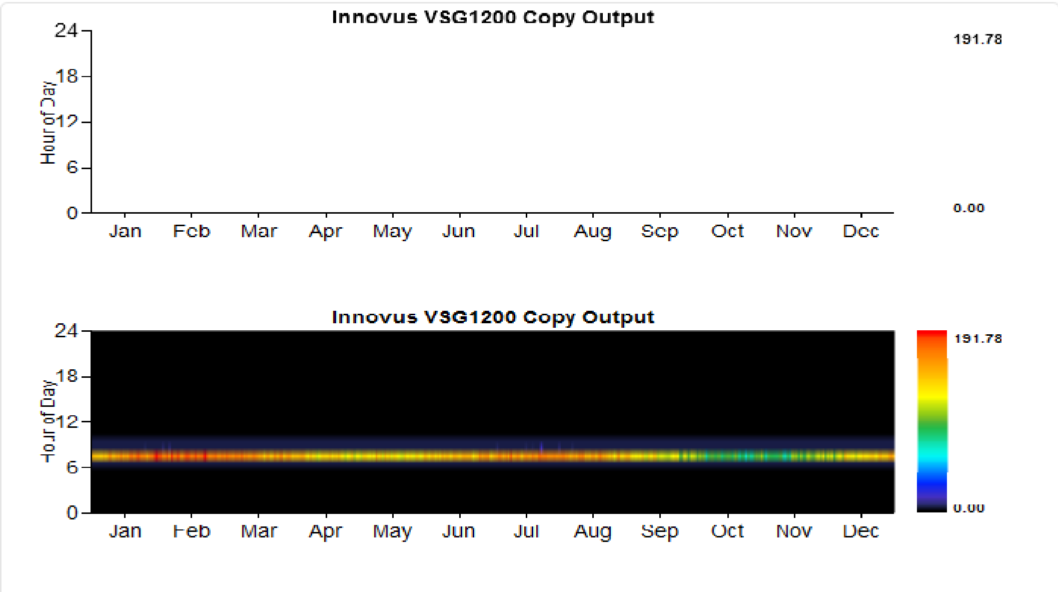


Generator: Innovus VSG1200 Copy:

Quantity	Value	Units
Hours of operation	1460	hrs/yr
Number of starts	365	starts/yr
Operational life	23	yr
Fixed generation cost	17.21	£/hr
Marginal generation cost	0.12	£/kWh
Electrical production	53692	kWh/yr
Mean electrical output	37	kW
Min. electrical output	3	kW
Max. electrical output	192	kW
Fuel consumption	18881	L/yr
Specific fuel consumption	0.35	L/kWh
Fuel energy input	185786	kWh/yr
Mean electrical efficiency	29	%



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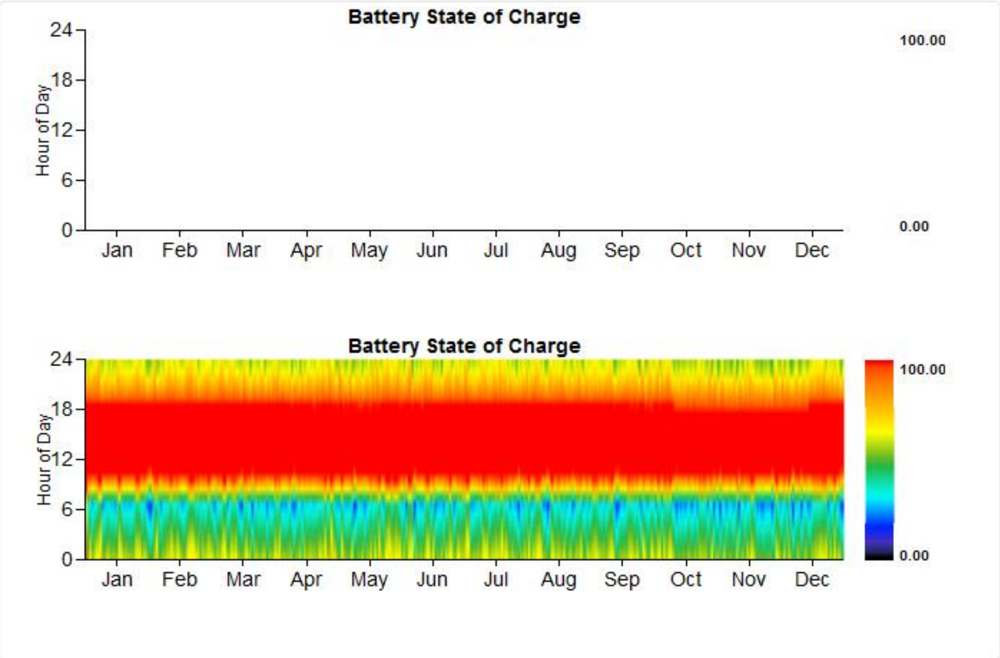
Battery: 280kW-1MWh Primus Power EnergyPod:

Quantity	Value
String size	1
Strings in parallel	1
Batteries	1
Bus voltage	840

Quantity	Value	Units
Nominal capacity	1008	kWh
Usable nominal capacity	1008	kWh
Autonomy	26	hr
Lifetime throughput	0	
Battery wear cost	0.000	£/kWh
Average energy cost	0.030	£/kWh
Energy in	302889	kWh/yr
Energy out	218429	kWh/yr
Storage depletion	411	kWh/yr
Losses	84049	kWh/yr
Annual throughput	257421	kWh/yr
Expected life	20	yr



Converter:

Quantity	Inverter	Rectifier	Units
Capacity	1,000	900	kW
Mean output	36	3	kWh/d
Minimum output	0	0	kW
Maximum output	124	114	kW
Capacity factor	4	0	%
Hours of operation	8,395	365	hrs/yr
Energy in	350,970	35,275	kWh/yr
Energy out	315,873	29,984	kWh/yr
Losses	35,097	5,291	kWh/yr

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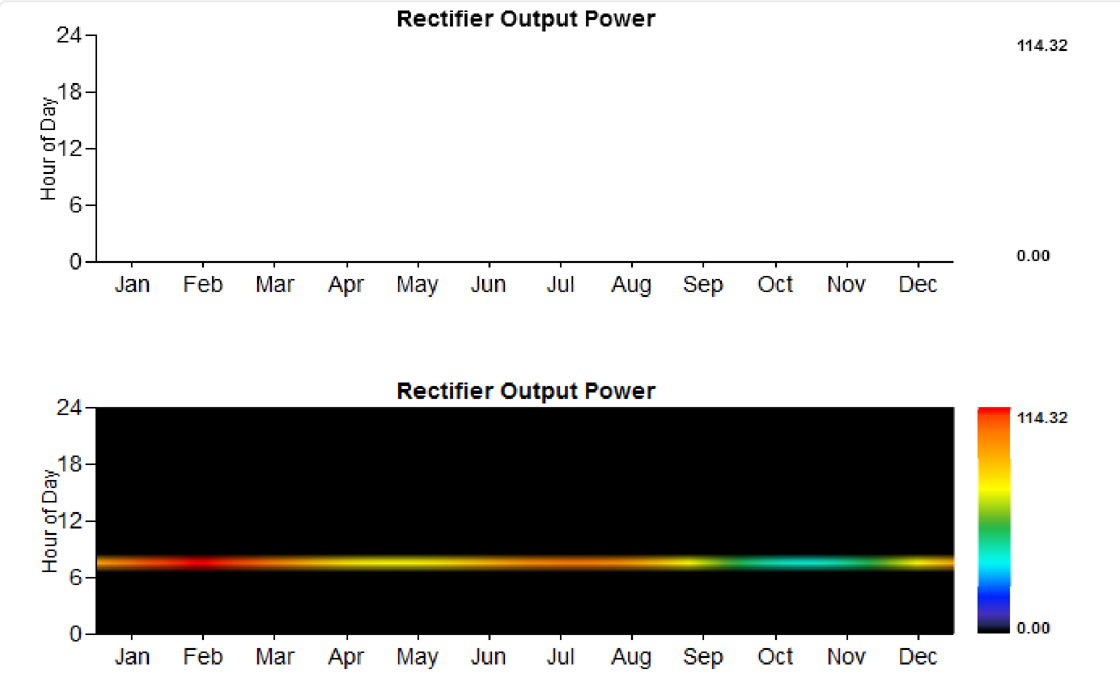

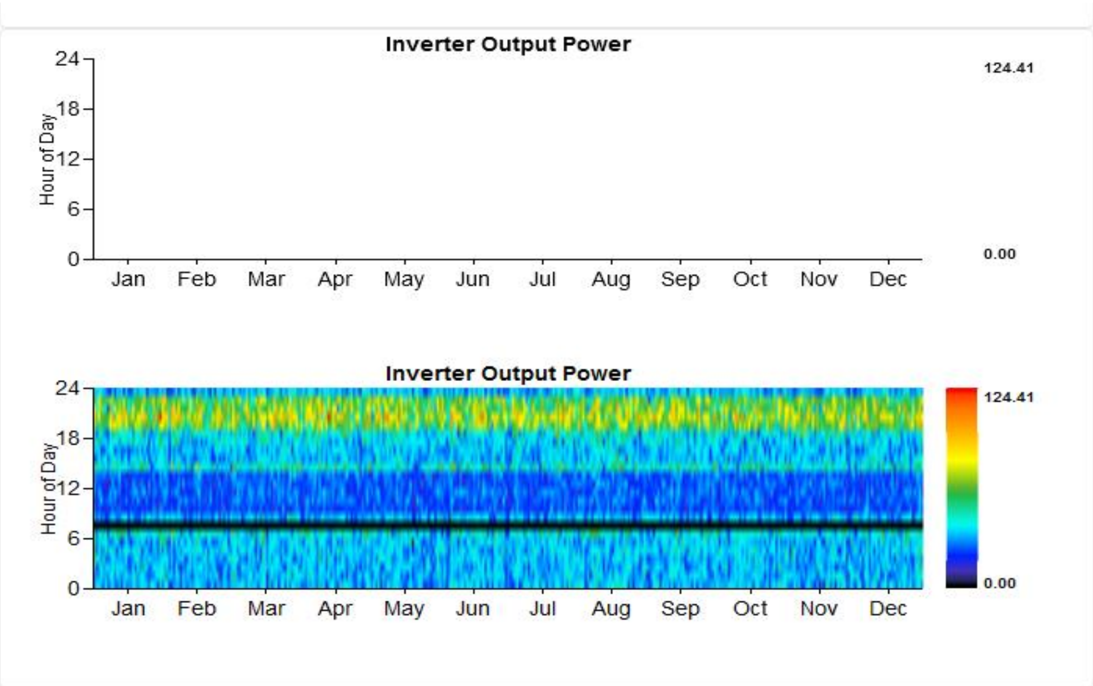

Emissions:

Pollutant	Emissions	Units
Carbon dioxide	49498	kg/yr
Carbon monoxide	262	kg/yr
Unburned hydrocarbons	14	kg/yr
Particulate matter	2	kg/yr
Sulfur dioxide	102	kg/yr
Nitrogen oxides	50	kg/yr

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4.1 Simulation Results:

The homer simulations provide the necessary information on the economic costs, electricity production and environmental characteristics of each system design. The simulations were carried out using all the parameters aforementioned in chapter three and the design and simulation for the existing diesel generator only, PV/DG system without retrofitting and PV/DG system when the lighting and pumps are assumed to be retrofitted was carried out. Each of these results can be explain using the economic costs, electricity production and environmental characteristics as follows.

4.2 Existing Diesel Generator System:

The homer software generates an estimation of lower initial capital cost of $1,188 with a very high annual operational cost of $27,509 for the existing DG. Cost of energy is very high $0.706/kwh and the generator consumed 13,006 liters of diesel for 6,570 hours within a year. This existing system proved to be lower in initial cost but very high operation and maintenance cost as shown in fig. 4.1 below.

Emission in kg/yr are very high for all the pollutant as shown in fig 4.4 below in the emission result of the simulation as result of DG supplying power only throughout the year as shown in fig. 4.2 and 4.3. figure 4.5 show total net present costs the existing station with high operation and other cost.

4.2.1 Economic Cost:

Operating cost and total NPC provide a better way of comparing the existing DG and PV.DG hybrid system in terms of economic cost derived from the proposed system. As shown from figure 4.1 above, the operating cost for DG only is very high (I.e. $27,509) compare to PV-diesel hybrid which has an annual operating cost of $5,591 after retrofitting and $6,421 before retrofitting. This shows that, if a station adopts the proposed system, a sum of $21,918 will be saved annual by the station investors.

The total NPC of the system is higher as compare to the existing DG system which is of $112,358 differences because the total NPC gives all the costs incurs over a lifetime of a system, minus the present value of all the revenue that a system earn over years..

4.2.2 Environmental Pollution:

The existing DG system operates throughout the year with a total fuel consumption of 13,006 liters of diesel which generate high emission rate 34250kg/yr of $CO_{2,}$ 84.5kg/yr of CO, 9.36kg/yr of UHC, 6.31 of PM, 68.8kg/yr of SO_2 and 75kg/yr of NOx as shown in figure 4.4. In contrast, the proposed system after retrofitting the station, allows the DG to operate for 1880 hours per annum with diesel consumption of 2679kg/yr of CO_2 , 17kg/yr of NOx. These results proved to be more secured as compare to the emission level when the filling station is not retrofitted, which diesel consumption of 3,465 liters per year and thereby increase emission by 912kg/yr of CO_2, 22.5kgyr of CO, 2.5kg/yr of UHC, 1.7kg/yr of PM, 18.3kg/yr of SO_2 and 20/kg/yr of NOx.

5. CONCLUSION

From the proposed design and simulation of PV/DG hybrid system simulated with Homer software, it has been proved that the proposed system is far better than the conventional existing DG system especially for filling stations in rural areas where grid supply is not available.

The economic analysis of the integrating PV/DG systems simulated in this thesis shows that filling stations investors should try and invest in PV/DG system instead of only DG despite the high initial cost which can be payback under 5 years by only the operating cost of DG. The cost of operation is very low compare to the operating cost of DG only. Also, the cost of energy is very low as seen from the simulated result which gives high rate of return to the investors with increase gain margin.

The hybrid power system simulation carried out on Akodo community shows that a 150kW array of solar panels and 20kW of wind turbines can be used to power the community, which has its peak load to be 89kW. Despite the intermittent nature of the two sources, the energy supplied using solar-wind hybrid power system could be reliable, as they complement each other and excess electricity is stored in the battery bank for use later. Though, there can be some factors like vandalization, theft case, flood and others which can cause the break- down of the system. The hybrid system can produce electrical energy to power appliances in the community, with solar panels producing 86% of the electrical energy while wind turbines produce 14%. The initial cost of implementing the solar-wind hybrid power system is estimated at $110,434,080*. The total lifespan of the project is proposed to be 25 years, while the salvage value of the entire system is estimated at $50,000,000*. In this study, it is shown that when the panels were sloped at 12^o they gave values for Net Present Cost and Levelised Cost of Energy which were lower than that of panels sloped at 15^o. Despite having high initial costs, renewable energy hybrid systems are long-term investments which are economically profitable, environmentally friendly and can cater for the electrical demand of remote communities lacking grid electricity.

6. RECOMMENDATION

Hybrid power systems can be a cost-effective means of supplying affordable and reliable power to rural communities where grid extension is expensive and difficult to deploy. Economic aspects of these technologies are sufficiently promising and could be included in power generation capacity for developing countries like ours. The developed model using the HOMER (Hybrid Optimization Model for Electric Renewables) software will help in sizing hybrid energy system hardware and in selecting the operating options for several components of the system, like the batteries and converters.

Research and development efforts should be cardinal in the area of renewable energy systems as a solution to the epileptic nature of power supply in Nigeria. Government at all levels are advised to invest massively in this alternative means of energy supply to power the isolated, remote and rural areas within the country. Community efforts and support from multinationals and non-governmental organisations should be encouraged in the provision of renewable energy system to compliment government's effort in this regard.

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